

1 PROGRAMMABLE THERMOSTAT INCORPORATING A LIQUID CRYSTAL DISPLAY
2 AND HAVING A FEATURE FOR MOUNTING HORIZONTALLY, VERTICALLY AND
3 ANY INTERMEDIATE ORIENTATION

4 Cross-Reference to Related Applications

5 This application is a continuation in part of pending United States Patent
6 Application No. 10/060,768 filed 01/30/2002. This application is related to: co-pending
7 United States Application No. 10/XXX,XXX entitled "Programmable Thermostat
8 Incorporating a Liquid Crystal Display Selectively Presenting Adaptable System Menus
9 Including Changeable Interactive Virtual Buttons" by Howard B. Rosen, filed on even
10 date herewith; and co-pending United States Application No. 10/XXX,XXX entitled
11 "Programmable Thermostat Including a Feature for providing a Running Total for the
12 Cost of Energy Consumed During a Given Period for Heating and/or Cooling a
13 Conditioned Space" by Howard B. Rosen, filed on even date herewith.

14 Field of the Invention

15 The present invention relates to a programmable thermostat incorporating an
16 interactive liquid crystal display (LCD), and, more particularly, to such a thermostat
17 which includes a feature for providing a running total for the cost of energy consumed
18 during a given period for heating and/or cooling a conditioned space.

19 Background of the Invention

20 Thermostats have been used for many years as temperature sensitive switches
21 which control heating and/or cooling equipment for conditioning a space in which the
22 thermostat, or a temperature sensor connected to the thermostat, is placed. In the well
23 known manner, a simple thermostat can be adjusted to establish a temperature set
24 point such that, when the temperature in the conditioned space reaches the set point,
25 the thermostat interacts with the heating and/or/cooling equipment to take suitable
26 action to heat or cool the conditioned space as may be appropriate for the season as
27 established by a user.

28 Modern thermostat systems, which take advantage of the ongoing rapid
29 advances in electronic technology and circuit integration, have many features which
30 provide more precise supervision of the heating and/or cooling equipment to achieve
31 more economical and more comfortable management of the temperature of a

1 conditioned space. Many modern thermostat systems include a real time clock, a
2 memory and a data processor to run a process control program stored in the memory;
3 Such thermostats accurately measure the temperature of a temperature sensor
4 disposed in the conditioned space and make decisions to send control signals to the
5 heating and/or cooling equipment in order to closely control the temperature of the
6 conditioned space. The use of programmed thermostat systems permits anticipating
7 and minimizing hysteresis or overshoot of the temperature in the conditioned space. In
8 addition, the program can specify different set points at different times of the day and
9 week and may also include a "vacation" mode which employs different set points when
10 the conditioned space is not occupied for an extended period.

11 Many modern thermostat systems are programmable by a user. Typically, prior
12 art programmable thermostat systems employ a set of fixed position, button-actuated
13 switches to be depressed in a precise sequence to program set points (which may vary
14 with the day of the week) for programmable time periods which may include a vacation
15 mode. The programming sequence may be followed on a separate display, typically an
16 LCD with segmented text characters. In some modern thermostats, "virtual" buttons are
17 presented on the LCD itself which is juxtaposed with a touch pad to effect an interactive
18 touch screen.

19 Outside of the art of programmable thermostat systems and programmable
20 thermostats, dot matrix LCDs, which have pixel display elements arranged in rows and
21 columns, are widely used. Dot matrix LCDs are not common as user-visible displays on
22 programmable thermostats for viewing alphanumeric and iconic graphic information
23 although such a thermostat is disclosed in, and particular features claimed in, co-
24 pending United States Patent Application No. 10/440,474, filed May 15, 2003, and
25 entitled: "Reverse Images in a Dot Matrix LCD for an Environmental Control Device" by
26 Howard B. Rosen, incorporated by reference herein.

27 This limited use of dot matrix LCDs in programmable thermostats is because of
28 basic engineering and practical considerations. Displayed information for a
29 programmable thermostat generally includes such things as environmental conditions,
30 heating and/or cooling equipment operation or non-operation, operational modes of the
31 thermostat and the like. The most important information in thermostat displays is

1 capable of being formed from segmented alphanumeric characters on less expensive
2 LCDs without dot matrix capability and with reduced requirements for memory and
3 programming.

4 Thus, dot matrix LCDs have not been widely used in prior art user programmable
5 thermostats through a failure to understand an extended functionality capability of those
6 devices when dot matrix LCDs are employed with a touch pad to effect an interactive
7 display. This extended functionality is exploited to advantage in the present invention
8 both to greatly simplify user programming and to relieve the manufacturer of the
9 necessity to fabricate variants of the thermostat to suit the control and display aspects
10 of various heating and/or cooling environments.

11 Thermostats incorporating a dot matrix LCD are generally rectangular in shape
12 and typically mounted with the long axis disposed horizontally. However, for both
13 practical and aesthetic reasons, it may be desirable to mount the thermostat with the
14 long axis disposed vertically. In the prior art thermostats, this has required the design
15 and production of two different models because of the necessary reorientation of the
16 display and user interface components.

17 Objects of the Invention

18 It is therefore a broad object of this invention to provide a field programmable
19 thermostat which may be user-configured for alternative horizontal and vertical
20 mounting positions.

21 It is a more specific object of this invention to provide a programmable
22 thermostat having a touch screen dot matrix LCD in which the pictorial presenting
23 information and virtual buttons on the touch screen is user configurable to be correctly
24 oriented whether the thermostat is mounted horizontally or vertically.

25 Summary of the Invention

26 Briefly, these and other objects of the invention are provided by a programmable
27 thermostat system for controlling space conditioning equipment and which includes: a
28 transparent touch pad juxtaposed with an LCD (preferably dot matrix) to constitute a
29 touch screen for interactive interface with a user; one or more environmental condition
30 sensors for providing an electrical signal indicative of the one or more sensed
31 environmental conditions of a conditioned space; and a processor including: a central

1 processing unit, a real time clock, a memory coupled to the central processing unit for
2 storing program and data information and an input/output unit coupled between the
3 processor and the touch screen for carrying out information transfer therebetween.

4 A program stored in the memory directs the central processing unit to
5 communicate through the input/output unit to selectively: establish on the LCD a
6 representation of at least one virtual button at a predetermined XY position; read the
7 same XY position on the touch pad to determine if the virtual button has been touched;
8 and if the virtual button has been touched, perform a predetermined action such as
9 moving to a different menu and/or changing operating criteria. An alphanumeric
10 message explaining the function of the virtual button is also displayed, and icon
11 indicators may be employed to unmistakably associate a message with a virtual button.
12 Different menus can place the virtual buttons and messages in various positions on the
13 touch screen to facilitate intuitive programming.

14 In accordance with the present invention, .

15 Description of the Drawing

16 The subject matter of the invention is particularly pointed out and distinctly
17 claimed in the concluding portion of the specification. The invention, however, both as
18 to organization and method of operation, may best be understood by reference to the
19 following description taken in conjunction with the subjoined claims and the
20 accompanying drawing of which:

21 FIG. 1A is a block diagram of a space conditioning system incorporating a
22 programmable thermostat according to the present invention;

23 FIG. 1 is a partially cut away schematic and top view of a thermostat with a
24 backlit dot matrix LCD employed as a display;

25 FIGs. 2 and 3 particularly illustrate a magnified section of the thermostat showing
26 two forms of displaying contrast in a dot matrix LCD;

27 FIGs. 4 and 5 are perspective and front views, respectively, of an exemplary
28 touch screen programmable thermostat of the present invention;

29 FIG. 6 is an exemplary pictorial of a first level interactive interface displayed on
30 the touch screen;

1 FIG. 7 is an exemplary pictorial of a second level interactive interface displayed
2 on the touch screen showing exemplary alternate contrast for a touch screen virtual
3 button;

4 FIG. 8 is an exemplary pictorial of a second level interactive interface displayed
5 on the touch screen with an exemplary sequence of virtual buttons available to a user
6 upon touching a single virtual button;

7 FIG. 9 is an exemplary pictorial of the second level interactive interface displayed
8 on the touch screen in FIG. 8 with a temporary "confirmation" virtual button for
9 accepting the change of the single virtual button;

10 FIG. 10 is an exemplary pictorial of a second level interactive interface displayed
11 on the touch screen in FIG. 8 with the function changed from "AUTOMATIC" to "COOL";

12 FIG. 11 is an exemplary pictorial of a menu displayed on the touch screen to
13 provide a first set of menu selections including an "ADVANCED SETTINGS" virtual
14 button;

15 FIG. 12 is an exemplary pictorial of another interactive interface displayed on the
16 touch screen showing "ADVANCED SETTINGS" menu selections after the
17 "ADVANCED SETTINGS" virtual button of FIG. 11 has been touched;

18 FIG. 13 is an exemplary pictorial of yet another interactive interface, reached by
19 touching an "ENERGY WATCH" virtual button displayed on the touch screen, for entering
20 settings for an "energy watch" mode;

21 FIG. 14 is an exemplary pictorial of a third menu interactive interface displayed
22 on the touch screen for the "energy watch" mode;

23 FIG. 15 is exemplary pictorial of an interactive interface displayed on the touch
24 screen of FIG. 8 as viewed in the device of FIG. 5 disposed in a horizontal mounting
25 position;

26 FIG. 16 is exemplary pictorial of the text and graphics of the interactive
27 interface displayed on the touch screen of FIG. 8 rotated for the device of FIG. 5
28 disposed in a vertical mounting position;

29 FIG. 17 is exemplary pictorial of an interactive interface displayed on the touch
30 screen of FIG. 12 as viewed in the device of FIG. 5 disposed in a horizontal mounting
31 position;

1 FIG. 18 is exemplary pictorial of the text and graphics of the interactive
2 interface displayed on the touch screen of FIG. 12 rotated for the device of FIG. 5
3 disposed in a vertical position; and

4 FIGs. 19 and 20 illustrate the manner in which different first level interface
5 screens may be reviewed and selected.

6 Detailed Description of the Preferred Embodiment(s)

7 Referring first to FIG. 1A, a user programmable thermostat system includes a
8 processor 1, a touch screen 2 and a temperature sensor 5 which is disposed in a
9 conditioned space 4. It will be understood that the processor 1 and the touch screen 2
10 are typically situated in a common housing (shown in an exemplary form in FIG. 5).
11 The sensor 5 may also be situated in the common housing or remotely as shown, all as
12 very well known in the art. The common housing is usually, but not necessarily, placed
13 in the conditioned space 4. Thus, those skilled in the art will understand that the block
14 diagram of FIG. 1A is very general in order to best explain the invention.

15 The processor 1 includes a central processing unit (CPU) 9 in communication
16 with a memory 8 for storing data and program information and also, via an input/output
17 unit (I/O unit) 10, a touch pad 11 and an LCD 12 which together constitute the touch
18 screen 2. The memory 8 may include a read-only part which is factory-programmed to
19 include the process control program and a random-access part which stores data
20 subject to change during operation. A settable real time clock 13 is used to keep time
21 in the thermostat system to facilitate diverse operations, such as establishing different
22 temperature set points (desired temperatures), during different periods of the day cycle.
23 An analog-to-digital converter 27 (which may not be required in all systems) serves to
24 convert any analog information received by the I/O unit 10 to digital information which is
25 suitable for use by the CPU 9. The thermostat system may be suitably powered by a
26 battery (not shown) and/or from equipment to which is connected.

27 Temperature information from the sensor 5 and output signals to a space
28 conditioning (heating and/or cooling) unit 3 pass through the I/O unit 10 under control of
29 the CPU 9 executing the process control program stored in the memory 8. Those
30 skilled in the art will understand that if the correspondents external to the processor 1
31 communicating with the CPU 9 are all digital in nature (e.g., if the temperature sensor 5

1 incorporates its own analog-to-digital converter and sends a digital representation of
2 temperature to the processor 1), then the I/O unit 10 may only constitute simple
3 switching circuits. The LCD may optionally be backlit by any suitable means (not shown
4 in FIG. 1A).

5 The heating/cooling equipment unit 3 may include one or more components such
6 as a heater, a compressor-type air conditioner, a heat pump, etc.

7 Thus, in the usual manner during normal operation, the temperature sensor 5
8 sends an electrical signal (e.g., if the sensor 5 is a simple thermistor, a resistance
9 value; several types of temperature sensors are widely used) representative of the
10 temperature within the conditioned space 4 which the processor can compare against a
11 previously entered set point to determine if control signals need to be sent to the space
12 conditioning equipment 3. For example, if the temperature in the conditioned space 4 is
13 found to be too low when operation is in the heating mode, the processor 1 signals the
14 space conditioning equipment 3 to circulate, through ducts 6, 7, air from/to the
15 conditioned space 4 which is heated by the space conditioning equipment before return
16 to the conditioned space. This heating phase continues until the sensor 5 indicates that
17 the space is now too hot (or approaching too hot) with reference to the set point such
18 that the processor 1 sends signal(s) to the space conditioning equipment 3 to cease the
19 heating function, all as very well known in the art. In a cooling mode, a counterpart
20 procedure is followed. Those skilled in the art will understand that the control process
21 typically includes such refinements as anticipation, hysteresis accommodation, fan
22 control, etc. which are acknowledged, but are not directly relevant to the invention.

23 It may be noted that integrated circuit chips including all the processor
24 components with all the necessary interface conditioning circuits are available off-the-
25 shelf and are under constant refinement for increased power. The subject invention
26 only requires the capabilities of a processor such as the processor 1, and off-the-shelf
27 integrated circuit processor chips may be used to advantage in the subject thermostat
28 system.

29 Thermostat systems may be user programmable or non-user programmable.
30 The present invention relates to programmable thermostat systems in which, in the prior
31 art, programming steps have been entered using a "tactile" touch pad while observing a

1 display which may be an LCD or some other display type. The drawbacks of the prior
2 art interactive thermostats have been discussed above. The present invention employs
3 a different type of thermostat user interface; viz., the touch screen 2, in which the touch
4 pad 11 and LCD 12 are integrated and coordinated as will be discussed below and
5 which, in conjunction with the processor 1, provides a programmable thermostat system
6 which is very much easier to program than in the prior art.

7 FIG. 1 shows a thermostat 100 having a processor 101 for controlling space
8 conditioning equipment in a manner equivalent to the discussion above. The processor
9 101 is electrically coupled with multiple connections 102 to a dot matrix LCD 104 whose
10 individual pixels 105 are driven by suitable signals to their respective vertical columns
11 and horizontal rows from the processor 101. Backlight panel 103 is shown for
12 illustration as separated from a backside of LCD 104 although it is known and preferred
13 that these two components be in close contact. Backlight panel 103 is connected to a
14 source of power and to processor 101 so that it can be turned on or off as needed or
15 desired.

16 The processor 101 also optionally includes a light sensor (not shown) for sensing
17 the illumination level in the space in which the LCD 104 is located, which illumination
18 may be compared with a previously entered minimum illumination value to determine
19 whether or not the room is darkened or dimly lit. If so, the display image can be
20 reversed to improve readability. Alternatively, as the processor 101 includes a real time
21 clock, an image reversal can be instituted at predetermined times of the 24-hour day.

22 Thus, FIG. 2 shows section 106 operated as it would typically appear during a
23 daytime or lighted room condition. The display elements of surrounding section 107 are
24 essentially clear and, optionally, backlight panel 103 shines through them to improve
25 readability. The display elements of image section 108 are partially or completely
26 opaque during daytime or in a lighted space. The combination of image section 108
27 and surrounding section 107 therefore displays system information readily
28 comprehensible and legible to a user in a lighted room.

29 FIG. 3 shows section 106 operated as it would during nighttime or in a dimly lit
30 room. The image has been reversed such that the display elements of the surrounding
31 section 107 are now partially or completely opaque, and light provided by backlight

1 panel 103 is partially or substantially completely blocked. But, the display elements of
2 image section 108 are now essentially clear, and the light from backlight panel 103
3 shines through them. The current system information is thereby comprehensible and
4 legible to a viewer in the darkened space. The result of this mode of operation is a
5 dimmer display which is suitable for low lighting conditions.

6 In another, similar, mode of operation, the reversible image can be repeatedly
7 reversed to "flash" all or selected items of the display upon the occurrence of certain
8 conditions as will be described below.

9 FIGs. 4 and 5 show an exemplary touch screen thermostat 110 with a housing
10 111 and touch screen 112 and incorporating the subject invention. Thermostat 110 has
11 no physical buttons at all; rather, all the functions and displayed information of the
12 programmable thermostat are available to a user by observation and interaction with
13 the touch screen 112. In the example, the touch screen 112 is generally rectangular,
14 thus having a long dimension and a short dimension.

15 FIG. 6 shows a first pictorial 113 presented on the touch screen 112 and
16 including: a column 114 of interactive virtual buttons 115, 116, 117; a "current
17 temperature" display 139; a "date" display 119; a "current time" display 120; a "heating
18 mode active" display 118; and a "cooling mode active" display 121. Pictorial 113
19 displays the word "AUTO" on virtual button 116 because the thermostat 110 is currently
20 operating in an "automatic" mode to control both a heater and an air conditioner to
21 respective set points shown in displays 118 and 121.

22 Pictorial 113 is a first level touch screen; i.e., a default first screen that is
23 normally viewed by a user when first approaching the thermostat 110. The information
24 conveyed to a user, during normal system operation of the exemplary current
25 configuration shown in FIG. 6, are: current ambient temperature, current date and time,
26 that a heater will turn on with reference to a set point of 21.5° C, that the air
27 conditioning system will turn with reference to a set point of 24.0° C, that the thermostat
28 110 is operating in the "AUTO" mode where both heating and air conditioning system
29 components are active and that the fan is responding to only the heating and air
30 conditioning modes (i.e., not always running).

1 When a user touches any active part of the touch screen in pictorial 113, the
2 overall display changes to pictorial 122, a second level touch screen shown in FIG. 7.
3 Virtual buttons 115, 116, and 117 still perform the functions described above. Newly-
4 presented virtual buttons 127 and 129 can be selectively touched at temperature
5 displays 128, and 130, respectively, to adjust the minimum and maximum set points.
6 FIG. 7 also illustrates that virtual button 116 may be touched and responsively changed
7 in step 123 by the control program to reverse contrast to be shown (in the same
8 position previously occupied by virtual button 116) as reversed contrast virtual button
9 124. In order to attract the user's attention to this button position, reversals can be
10 made in short intervals so that the virtual button 116 appears to be flashing. This
11 "flashing" emphasizes the fact that the thermostat 110 is currently operating in a
12 particular state or condition and that a user may want to change the operating state or
13 condition of the thermostat 110. Touching virtual button 183 directs the control system
14 to another mode of operation which will be discussed further below.

15 FIGs. 8 to 10 show pictorial 122 in various interactive conditions. FIG. 8
16 illustrates that virtual button 116 can undergo step 131 in response to a user touch
17 which also causes a change in the operating state of thermostat 110 and a change of
18 the legend associated with virtual button 116 to one of the virtual buttons in column
19 132. In the example, successive steps 133 to 137 indicate that a user has touched
20 virtual button 116 one or more times to cause the operating state of thermostat 110 and
21 the legend of virtual button 116 to change with respect to those steps as follows:

22 A) at step 137, from "automatic" mode to "off" mode (none of the environmental
23 control equipment connected with thermostat 110 will operate, and virtual button 116
24 shows "OFF");

25 B) at step 133, from "off" mode to "heat" mode (a heater or a heat pump in heat
26 mode operates to heat the conditioned space, and virtual button 116 shows "HEAT");

27 C) at step 134, from "heat" mode to "cool" mode (an air conditioner or heat pump
28 operating in the cooling mode operates to cool the conditioned space, and virtual button
29 116 shows "COOL");

1 D) at step 135, from "cool" mode to "emergency heat" mode (a backup electric
2 heater operates to keep the conditioned space temperature above a lowest set point,
3 and virtual button 116 shows "EMER HEAT"); and

4 E) at step 136, from "emergency heat" mode to "automatic" mode (the air
5 conditioner and heater (or heat pump) operates in both the "heat" and "cool" mode, and
6 virtual button 116 shows "AUTO").

7 FIGs. 9 and 10 illustrate an exemplary operation of changing, confirming and
8 showing the change made by touching virtual button 116 twice. FIG. 9 shows that,
9 under control of the process control program, virtual button 116 has already responded
10 to step 133 to briefly change from the "auto" mode to the "heat" mode on the first touch
11 and, on the second touch, has changed from the "heat" mode to the "cool" mode; and
12 that a temporary active virtual button 138 is now displayed for a user to confirm that the
13 user wishes to select the currently displayed function; i.e., "cool". Touching virtual
14 button 138 under these conditions causes the changes seen in FIG. 10. It will be
15 particularly noted in FIG. 10 that, as a feature of the system, display 118 has
16 disappeared since the "auto" mode is no longer operational because no heating
17 function is active. Display 121 is still present in FIG. 10 because the "cool" mode is
18 operational. Should the "heat" mode be selected and 'HEAT' shown with virtual button
19 116, display 121 will disappear and display 118 will reappear. In the "off" mode, both
20 displays 118 and 121 will disappear.

21 It will be appreciated that the virtual buttons of virtual buttons column 132 may
22 alternatively be reduced in size and distributed on the surface of pictorial 113 instead of
23 being a set of virtual buttons activated and serially viewable by invoking steps 133-137.
24 If the virtual buttons of virtual buttons column 132 are distributed as separately and
25 simultaneously viewable virtual buttons, it is desirable that the virtual button for the
26 function currently activated for thermostat 110 will "flash" in contrast as described above
27 so that the user will know which of the operating states or conditions are currently
28 controlled by thermostat 110.

29 However, it is an important feature of the thermostat 110 that, although a user
30 may touch virtual button 116, fewer or more than all the virtual buttons of column 132,
31 in the example, and their associated changes in the normal operation control effected

1 by thermostat 110 may be available to a user. The user has the ability to "edit" and/or
2 simplify the virtual buttons column 132 to reflect the user's environmental control
3 equipment actually connected for control by thermostat 110.

4 If fewer than or more than the virtual buttons of virtual buttons column 132 are
5 available to the user, appropriate fewer or more touching steps will be required to cycle
6 through the functions of thermostat 110 and the corresponding legends which may
7 appear with virtual button 116. The particular sequence of thermostat functions
8 available at steps 133 to 137 is only exemplary of how normal user changes between
9 operating states or conditions are made for thermostat 110; the virtual buttons of
10 column 132 may, of course, have a different sequence and also reflect various space
11 conditioning equipment components which may be installed in diverse applications.

12 Thus, as more fully described below, a user is able, typically during a system
13 setup, to eliminate or add to the virtual buttons shown in column 132 (and their
14 associated functions) by using the touch screen in a manner that allows the user to
15 specify what environmental control equipment components are actually controlled by
16 thermostat 110 and, accordingly, included in column 132.

17 In practice, the thermostat manufacturer provides, in the control program, control
18 sequences for as many different types of space conditioning components as might be
19 used in widely diverse applications, alone or in combination. During setup, the user of a
20 given installation eliminates those components, and graphics displays related thereto,
21 which are irrelevant to the given installation, thus simplifying later ongoing programming
22 and use of the thermostat. This system setup procedure is instituted by touching the
23 "MENU" button 183 shown in FIG. 7 which the control program responds to by
24 displaying second-level pictorial 140 on the touch screen.

25 FIG. 11 shows that pictorial 140 displays virtual buttons 141 to 149. Touching
26 each of buttons 141 to 149 results in a new, usually third level, pictorial screen to show
27 information and/or new buttons as follows:

28 A) for "home" icon button 141, a return to the first level, normal operation,
29 pictorial 113 shown in FIG. 6;

30 B) for "DATE/TIME SETTINGS" button 142, for entering current date and time
31 information;

1 C) for "SET SCREEN" button 145, for changing screen settings for the touch
2 screen;

3 D) for "CLEAN SCREEN" button 146 to wipe the screen, e.g., with a lightly
4 dampened cloth, without accidentally changing any of the settings; this function times
5 out after a few seconds;

6 E) for button "FILTER MONITOR" button 147, entering, for display at pictorial
7 113 or similar touch screen, a reminder to change or clean filters on a specified
8 schedule;

9 F) for "VACATION SETTINGS" button 148, for entering appropriate vacation
10 system settings;

11 G) for "PROGRAM SETTINGS" button 143, for entering automatic temperature
12 set point adjustments, typically for each of four selectable times for each day of the
13 week;

14 H) for "ENERGY WATCH" button 144, for display of ongoing energy
15 consumption and costs as discussed further below; and

16 I) for "ADVANCED SETTINGS" button 149, for entering the environmental
17 control equipment connected with thermostat 110, entering energy consumption data
18 and costs and other functions as described.

19 Touching virtual button 149 results in display of pictorial 150 of FIG. 12. In a
20 manner similar to button 116 of FIG. 8, buttons 154 and 158 of FIG. 12 each represents
21 a sequence of buttons that change after being touched by a user. Button 154
22 represents the presence or absence of air conditioning equipment connected with
23 thermostat 110. Button 158 represents the presence or absence of heating equipment
24 connected with thermostat 110.

25 More particularly, the virtual buttons in column 163 are those that become
26 successively visible when a user successively touches button 154, also indicating a
27 change in the designation of which cooling equipment is present in a given system.
28 Similarly, in the example, buttons in column 164 are those that become successively
29 visible when a user successively touches button 158, also indicating a change in the
30 designation of which heating equipment is present in the given system.

1 In the example, invoking steps 160, 161 and 162 respectively cause a change in
2 the function and legend appearing at button 154 from "heat pump" mode to "air
3 conditioner" mode, from "air conditioner" mode to "no compressor" mode (no air
4 conditioning equipment), and from "no compressor" mode to "heat pump" mode. The
5 memory program contains programming adapted to cause effective operation of a heat
6 pump or compressor type air conditioner depending on the one selected at button 154.
7 If the "no compressor" mode is selected at button 154, the buttons column 132 of FIG.
8 will lack the "cool" and "auto" buttons and functions.

9 Cycling through steps 165, 166, 167, 168 and 169 respectively cause a change
10 in the function and legend at button 158 from "electric furnace" mode (presence in the
11 given system of an electric powered furnace) to "emer. elect. furnace" mode (additional
12 presence of an emergency electric furnace), from "emer. elect. furnace" mode to "gas
13 furnace" mode (presence of a gas furnace), from "gas furnace" mode to "oil furnace"
14 mode (presence of an oil furnace), from "oil furnace" mode to "furnace off" mode (lack
15 of heating equipment) and from "furnace off" mode to "electric furnace" mode. If the
16 "furnace off" mode is selected at button 158, the buttons column 132 of FIG. 8 will lack
17 the "heat" and "emer heat" mode buttons and functions as well as the "auto" mode
18 button and function. The control program stored in memory contains routines adapted
19 to cause effective operation of any combination of the designated equipment.

20 Pictorial 155 of FIG. 12 also shows virtual button 151 for changing the
21 temperature designation in the touch screen from Centigrade to Fahrenheit, buttons
22 153 and 157 for entering certain set point related parameters, button 155 for entering
23 an installer message and button 146 for entering security settings.

24 FIG. 13 shows pictorial 171 which is activated by a user's touching button 152 of
25 FIG. 12. Pictorial 171 is a menu permitting entry of energy requirement and cost
26 information using cost determination information entry virtual buttons 172, 173, 174 and
27 175. Touching button 172 changes the numerical legend in increments to indicate
28 kilowatts per hour required of a compressor if air conditioning equipment is present.
29 Thus, the user is able to enter into the energy required for operation of a cooling
30 component in the system. In a similar manner for buttons 173 and 174, a user can
31 enter the energy requirements for a heating furnace or heat pump if in the system and

1 that of a system fan. Button 175 allows the user to enter the per kilowatt hour cost of
2 energy in the user's locality. The equipment energy requirements and energy cost are
3 stored in the memory and used by the control program to calculate and display
4 cumulative energy used and cumulative cost of that energy for a monitored period. The
5 memory stores in a cumulative amount the periods in which the air conditioner, furnace,
6 heat pump, fan and/or other environmental control equipment operates, and calculates
7 and displays, as shown in pictorial 176 of FIG. 14 the running energy cost information.
8 In the example, display 177 shows the number of days for which the energy information
9 has been accumulated. Displays 178, 179, 179, and 180 show energy used by
10 respectively and cumulatively the air conditioning compressor, the furnace and the fan,
11 with the total energy being used by that equipment in display 181 and the total cost of
12 that energy shown in display 182.

13 It will be understood that the user, with a few button manipulations, can easily
14 determine what the running cost is for the use of the environmental control equipment
15 in the user's system. In the example, the user can successively touch: an active part of
16 the touch screen of pictorial 113 of FIG. 6, the "MENU" button 183 of pictorial 122 of
17 FIG. 8 and the "ENERGY WATCH" button 144 of pictorial 140 of FIG. 11 to arrive at the
18 display of FIG. 14. Alternatively, the "ENERGY WATCH" button 144 can instead or
19 also be provided on the touch screen of pictorial 113 of FIG. 6 so that a single button
20 touch at the first level interface will bring the touch screen directly to the display of FIG.
21 14.

22 Attention is now directed to FIG. 15 which shows that pictorial 113 has
23 alphanumeric text on the buttons and displays disposed horizontally for easy reading,
24 as does the same alphanumeric text on the same buttons and displays in pictorial 113A
25 of FIG. 16. However, the housing 111 of FIG. 15 has been rotated 90 degrees to obtain
26 the vertical orientation of the housing 111 of FIG. 16. The control program of
27 thermostat 110 can reorient the display from that shown in pictorial 113 to that shown in
28 pictorial 113A by suitably remapping the column and row drive signals to the individual
29 pixels of the LCD. This feature can be invoked, in one embodiment, by touching the
30 "SCREEN SET" button 145 of pictorial 140 shown in FIG. 11 for a predetermined period
31 of time (say five seconds), which action is sensed by the control program to cause a

1 change of pictorial 113 to pictorial 113A or vice versa. All the pictorials for the touch
2 screen for the thermostat 110 would be similarly reoriented, and FIGs. 17 and 18 show
3 a similar translation of pictorial 155 to pictorial 155A.

4 This feature is not limited to a translation of only 90 degrees of the alphanumeric
5 text, graphics and buttons of thermostat 110 as described above. The memory
6 program, combined with the capability of a dot matrix type LCD, with its individually
7 addressable pixels disposed in rows and columns, can cause a rotation of all those
8 aspects of the touch screen to be rotated incrementally through 360 degrees so that a
9 user can mount the housing 111 in whatever angled orientation is desired.

10 Attention is now directed to FIG. 19 in which pictorial 184 is obtained by touching the
11 "SET SCREEN" button 145 of pictorial 140 shown in FIG. 11 for a predetermined period
12 of time (say five seconds). This touching action is sensed by the control program which
13 causes a display change from pictorial 140 shown in FIG. 11 to the pictorial 184 shown
14 in FIG. 19. Pictorial 184 contains a sub-pictorial 185 that is a framed and generalized
15 inactive version of first level interactive pictorial 113 shown in FIG. 6. The user sees in
16 sub-pictorial 185 a general layout of virtual buttons, text and graphics that can be
17 selected to view as the pictorial of the first level interactive interface. This user
18 selection can be made if the "SET SCREEN" button 145 of pictorial 184 shown in FIG.
19 is not touched for a predetermined period of time (say five seconds). However, the
20 user can select other general layouts of virtual buttons, text and graphics that will
21 thereafter be seen at the first level interactive interface.

22 Thus, referring now to FIG. 20. pictorial 186 contains a sub-pictorial 187 that is
23 an alternate general layout of virtual buttons, text and graphics for the first level
24 interactive interface that can be selected by a user. Sub-pictorial 187 appears if virtual
25 button 145 is touched for a predetermined period of time (say five seconds). In sub-
26 pictorial 187, a row of virtual buttons 191 are aligned along a top part of sub-pictorial
27 187 which will become the first level interactive interface shown in FIG. 8 when normal
28 operation is resumed. When a return is made to the alternative first level interactive
29 interface, touching any one of the virtual buttons 191 causes the control program of the
30 thermostat to change operating states to one associated with that one virtual button. In
31 one embodiment, a touched virtual button 191 is visually distinguished from the other

1 virtual buttons 191 so the user knows which operating state currently controls the
2 thermostat. One form of effecting that visual distinction is shown for virtual button 188.
3 Virtual button 188 after being touched causes the control program to change the
4 operating state of the thermostat to an "automatic" mode (the air conditioner and heater
5 together, or a heat pump, operates in both the "heat" and "cool" modes, and virtual
6 button 188 shows "AUTO"). Thereafter, the visible representation of virtual button 188
7 changes according to step 190 to the contrasting virtual button 189 and back to the
8 form shown for virtual button 188 at short intervals to simulate a "flashing" virtual button.
9 Virtual buttons 191 represent the same operating states represented by the similarly
10 named virtual buttons of virtual buttons in column 132 shown in FIG. 8.

11 FIGs. 19 and 20 represent only two of many possible arrangements of virtual
12 buttons, text and graphics that can be made available for selection by a user for the first
13 level interactive interface. In the above exemplary method of making that selection, the
14 user touches or refrains from touching the "SET SCREEN" button 145. This feature
15 extends the ability of the user to select from one of several arrangements of virtual
16 buttons, text and graphics at any of the levels of interactive or passive (information or
17 graphics only) interface of the thermostat. This feature may be implemented by steps
18 other than touching or refraining from touching the "SET SCREEN" button 145.

19 While the principles of the invention have now been made clear in an illustrative
20 embodiment, there will be immediately obvious to those skilled in the art many
21 modifications of structure, arrangements, proportions, the elements, materials, and
22 components, used in the practice of the invention which are particularly adapted for
23 specific environments and operating requirements without departing from those
24 principles.